CHAPTER 16

EROSION AND SEDIMENT CONTROL

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16.1 EROSION AND SEDIMENT CONTROL POLICIES

16.1.1 Background

Erosion and sedimentation are natural or geologic processes whereby soil materials are detached and transported from one location and deposited in another, primarily due to rainfall and runoff. Accelerated erosion and sedimentation can occur at times in conjunction with highway and transportation facility construction. This accelerated process can result in significant impacts such as safety hazards, expensive maintenance problems, unsightly conditions, instability of slopes and disruption of ecosystems, costly penalties, and cease-and-desist orders resulting in project delay. For this reason, the total design process must be performed considering the minimization of erosion and sedimentation. General erosion and sediment control guidance can be found in Chapter 3 of the *AASHTO Highway Drainage Guidelines (2)*.

16.1.2 Federal Policy

As a result of the National Environmental Policy Act of 1969, much attention has been directed to the control of erosion and sedimentation. As a result of this concern, numerous State and Federal regulations and controls governing land disturbing activities have been developed and published. There are also Federal control requirements exerted by numerous agencies (USACE, USEPA, USFWS) through their administration of various permitting requirements (Section 404, Section 402 and the NPDES Program of the Federal Water Pollution Control Act (FWPCA), Sections 9 and 10 of the Rivers and Harbors Act, and the National Pollutant Discharge Elimination System (NPDES) permit).

A NPDES permit requires a Stormwater Pollution Prevention Plan for industrial activities (including construction) for undisturbed areas of 1 acre or more. For those States that do not operate under delegated authority for Sediment and Erosion Control, a Notice of Intent (NOI) is required. The NOI is a USEPA, NPDES form titled "Notice of Intent (NOI) for Storm Water Discharges Associated with CONSTRUCTION ACTIVITY Under a NPDES General Permit".

16.1.3 AASHTO Policy

The policy for erosion and sediment control is stated in AASHTO *A Policy on Geometric Design of Highways and Streets (1),* as follows:

> "*Erosion prevention is one of the major factors in design, construction and maintenance of highways. It should be considered early in the location and design stages. Some degree of erosion control can be incorporated into the geometric design, particularly in the cross section elements. Of course, the most direct application of erosion control occurs in drainage design and in the writing of specifications for landscaping and slope planting.*
>
> *Erosion and maintenance are minimized largely by the use of flat side slopes, rounded and blended with natural terrain; serrated cut slopes; drainage channels designed with due regard to width, depth, slopes, alignment and protective treatment; inlets located and spaced with erosion control in mind; prevention of erosion at culvert outlets; proper facilities for groundwater interception; dikes, berms and other protective devices to trap sediment at strategic locations; and protective ground covers and planting.*"

Although some standardization of methods for minimizing soil erosion in highway construction is possible, national guidelines for erosion control are of a general nature because of the wide variation in climate, topography, geology, soils, vegetation, water resources and land use encountered in different parts of the nation.

16.1.4 State Policy

The state of Utah has enacted some form of erosion and sediment control program through specific legislated sediment control acts or as a part of their Section 208 (PL 92-500) planning.

UDOT has a qualified staff to prepare specifications for planting and establishing ground cover, trees, shrubs, vines and various erosion control measures. Qualified personnel within the the Department should be consulted in the preparation of plans and in supervising erosion control construction.

Natural Resources Conservation Service (NRCS) field offices of the US Department of Agriculture, seed suppliers, erosion control contractors and various State agencies can provide valuable assistance to the Department in solving local erosion problems by suggesting vegetation suitable for the locality. Aerial photographs can be used to identify soil types and study land forms and erosion potential.

16.1.5 Program

Because modern highway construction may involve the disturbance of large land areas, control of erosion and sedimentation is a major concern. A commitment to erosion and sediment prevention during all phases of highway design, construction and maintenance is essential.

Although much of the effort for control of erosion and sedimentation is expended during the construction phase of a highway development, a successful program must address erosion and sedimentation during the planning, location, design and future maintenance phases as well. The erosion and sediment control program should be a plan of action and include contract documents to achieve an acceptable level of control within established criteria and control limits. This plan of action is analogous to an Agency's highway development process that results in contract plans and documents to provide and maintain transportation facilities based on certain criteria and controls.

16.2 EROSION AND SEDIMENT CONTROL PLAN

16.2.1 Guidelines

The design of erosion and sediment control systems involves the application of common-sense planning, scheduling and control actions that will minimize the adverse impacts of soil erosion, transport and deposition. The following basic guidelines govern the development and implementation of a sound erosion and sediment control plan:

- The project should be planned to take advantage of the topography, soils, waterways and natural vegetation at the site.
- The smallest practical area should be exposed for the shortest possible time.

- Onsite erosion control measures should be applied to reduce the gross erosion from the site.

- Sediment control measures should be used whenever possible to prevent offsite damage.

- A thorough maintenance and follow-up program should be implemented.

In practice, these guidelines should be tied together in the planning process, which identifies potential erosion and sediment control problems before construction begins.

16.2.2 Control Measures

Control measures, such as stabilizing emulsions and vegetation, are required for all disturbed areas. Vegetation measures generally include retention or provision of strips of vegetation to provide a filtration buffer, temporary seeding, permanent seeding, sodding and mulching. Structural control measures are required where potentially damaging, sediment-laden runoff leaves a disturbed site and generally include sediment traps, diversions, sediment basins and permanent drainage facilities.

The erosion and sediment control plan shall be a part of the construction proposal including appropriate construction specifications for all control measures. These specifications shall be developed in consultation with the designer as required for site-specific conditions. Typical specifications may be obtained from erosion control references such as Reference *(4)*.

16.3 FACTORS INFLUENCING EROSION

16.3.1 Principal Factors

The inherent erosion potential of any area is determined by four principal factors — soil characteristics, vegetative cover, topography and climate. Although each is discussed separately herein, they are interrelated in determining erosion potential.

16.3.2 Soil Characteristics

The properties of soil that influence erosion by rainfall and runoff are those that affect the infiltration capacity of a soil and those that affect the resistance of a soil to detachment and being carried away by falling or flowing water. Soils containing high percentages of fine sands and silt are normally the most erodible. As the clay and organic matter content of these soils increases, the erodibility decreases. Clays act as a binder to soil particles, thus reducing erodibility. However, although clays have a tendency to resist erosion, once eroded they are easily transported by water. Soils high in organic matter have a more stable structure that improves their permeability. Such soils resist raindrop detachment and infiltrate more rainwater. Clear, well-drained and well-graded gravels and gravel-sand mixtures are usually the least erodible soils. Soils with high infiltration rates and permeabilities reduce the amount of runoff.

16.3.3 Vegetative Cover

Vegetative cover plays an important role in controlling erosion in the following ways:

- shields the soil surface from the impact of falling rain,
- holds soil particles in place,

- maintains the soil's capacity to absorb water,
- slows the velocity of runoff, and
- removes subsurface water between rainfalls through the process of evapotranspiration.

By limiting and staging the removal of existing vegetation and by decreasing the area and duration of exposure, soil erosion and sedimentation can be significantly reduced. Special consideration should be given to the maintenance of existing vegetative cover on areas of high-erosion potential such as erodible soils, steep slopes, drainageways and the banks of streams.

16.3.4 Topography

The size, shape and slope characteristics of a watershed influence the amount and rate of runoff. As both slope length and gradient increase, the rate of runoff increases, and the potential for erosion is magnified. Slope orientation can also be a factor in determining erosion potential.

16.3.5 Climate

The frequency, intensity and duration of rainfall are fundamental factors in determining the amounts of runoff produced in a given area. As both the volume and velocity of runoff increase, the capacity of runoff to detach and transport soil particles also increases. Where storms are frequent, intense or of long duration, erosion risks are high. Seasonal changes in temperature, and variations in rainfall, help to define the high erosion risk period of the year. When precipitation falls as snow, no erosion will take place. However, in the spring the melting snow adds to the runoff and erosion hazards are high. Because the ground is still partially frozen, its absorptive capacity is reduced. Frozen soils are relatively erosion-resistant. However, soils with high moisture content are subject to uplift by freezing action and are usually very easily eroded upon thawing.

16.4 TECHNICAL PRINCIPLES

16.4.1 Introduction

For an erosion and sediment control program to be effective, it must be considered and measures taken in the project planning stage. These planned measures, when conscientiously and expeditiously applied during construction, will result in orderly development without environmental degradation. From the previous discussion on erosion and sedimentation processes and the factors affecting erosion, basic technical principles can be formulated to assist the designer in providing effective erosion and sediment control. These principles should be utilized to the maximum extent possible on all projects.

16.4.2 Principles

1. Plan the highway project to fit the particular topography, soils, drainage patterns and natural vegetation as practicable. Areas with steep slopes, erodible soils and soils with severe limitations should be avoided where possible.

2. Minimize the extent and the duration of exposure. Plan the phases or stages of construction to minimize exposure. All other areas should have a good cover of temporary or permanent vegetation or mulch. Grading should be completed as soon as possible after its initiation. Then, immediately after grading is complete, permanent vegetative cover should be

established in the area. As cut slopes are made and as fill slopes are brought up to grade, these areas should be revegetated as the work progresses.

3. Apply erosion control practices to prevent excessive on-site damage. This principle relates to using practices that control erosion on a site to prevent excessive sediment from being produced. Keep soil covered as much as possible with temporary or permanent vegetation or with various mulch materials. Special grading methods, such as roughening a slope on the contour or tracking with a cleated dozer, may be used. Other practices include diversion structures to divert surface runoff from exposed soils and grade stabilization structures to control surface water. “Gross” erosion in the form of gullies must be prevented by these water control devices.

4. Apply perimeter control practices to protect the disturbed area from off-site runoff and to prevent sedimentation damage to areas below the construction site. This principle relates to using practices that effectively isolate the construction site from surrounding properties and, especially, to controlling sediment once it is produced and preventing its transport from the site. Diversions, dikes, sediment traps, vegetative and structural sediment control measures can be classified as either temporary or permanent depending on whether or not they will remain in use after construction is complete.

   Generally, sediment can be retained by two methods: (a) filtering runoff as it flows through an area, and (b) impounding the sediment-laden runoff for a period of time so that the soil particles settle out. The best way to control sediment, however, is to prevent erosion.

5. Keep runoff velocities low and retain runoff on the site. The removal of existing vegetative cover and the resulting increase in impermeable surface area during construction will increase both the volume and velocity of runoff. These increases must be considered when providing for erosion control. Keeping slope lengths short and gradients low and preserving natural vegetative cover can keep stormwater velocities low and limit erosion hazards. Runoff from development should be safely conveyed to a stable outlet using storm drains, diversion, stable waterways or similar measures. Conveyance systems should be designed to withstand the velocities of projected peak discharges. These facilities should be operational as soon as possible.

6. Stabilize disturbed areas immediately after final grade has been attained. Permanent structures, temporary or permanent vegetation, mulch, stabilizing emulsions or a combination of these measures should be employed as quickly as possible after the land is disturbed. Temporary vegetation and mulches and other control materials can be most effective where or when it is not practical to establish permanent vegetation or until the vegetation is established. Such temporary measures should be employed immediately after rough grading is completed, if a delay is anticipated in obtaining finished grade. The finished slope of a cut or fill should be stable and ease of maintenance should be considered in the design. Stabilize roadways, parking areas and paved areas with a gravel subbase wherever possible.

7. Implement a thorough maintenance and follow-up program. This principle is vital to the success of the six previous principles. A site cannot be effectively controlled without thorough, periodic checks of the erosion and sediment control practices. These practices must be maintained just as construction equipment must be maintained and material

checked and inventoried. An example of applying this principle would be to start a routine "end-of-day check" to make sure that all control practices are working properly.

Usually, these seven principles are integrated into a system of vegetative measures and structural measures and management techniques to develop a plan to prevent erosion and control sediment. In most cases, a combination of limited time of exposure and a judicious selection of erosion control practices and sediment trapping facilities will prove to be the most practical method of controlling erosion and the associated production and transport of sediment.

16.5 GENERAL CRITERIA FOR CONTROLLING EROSION

16.5.1 Application

The general criteria are minimum requirements for controlling erosion and sedimentation from "land-disturbing activities." These general criteria work in concert with individually developed erosion and sediment control plans. They establish minimum standards of soil conservation practices that apply to all land-disturbing projects.

16.5.2 General Criteria

Following is a discussion of the general criteria that shall be considered in developing an erosion and sediment control plan.

16.5.2.1 Stabilization

The following refers to stabilization of denuded areas and soil stockpiles:

1. Permanent or temporary soil stabilization shall be applied to denuded areas within 14d after final grade is reached on any portion of the site. Soil stabilization shall also be applied within 14 d to denuded areas that may not be at final grade but will remain dormant (undisturbed) for longer than 35 d.

   Soil stabilization refers to measures that protect soil from the erosive forces of raindrop impact and flowing water. Applicable practices include temporary erosion control material, vegetative establishment, mulching and the early application of a gravel base on areas to be paved. Soil stabilization measures should be selected to be appropriate for the time of year, site conditions and estimated duration of use.

2. Soil stockpiles shall be stabilized or protected with sediment trapping measures to prevent soil loss.

16.5.2.2 Permanent Vegetation

A permanent vegetative cover shall be established on denuded areas not otherwise permanently stabilized.

16.5.2.3 Protection of Adjacent Property

Properties adjacent to the site of a land disturbance shall be protected from sediment deposition. This may be accomplished by preserving a well-vegetated buffer strip around the lower perimeter of the land disturbance, by installing perimeter controls such as sediment barriers, filters, or dikes or sediment basins, or by a combination of such measures.

16.5.2.4 Timing and Stabilization

Sediment basins and traps, perimeter dikes, sediment barriers and other measures intended to trap sediment on-site shall be constructed as a first step in grading and become functional before upslope land disturbance occurs. Earthen structures such as dams, dikes and diversions shall be stabilized within 14 d of installation.

16.5.2.5 Sediment Basins

Stormwater runoff from drainage areas with 5 ac or greater disturbed area shall pass through a sediment basin or other suitable sediment-trapping facility. Sediment basins are more cost effective when most of the area draining to the basin is disturbed area, because they must be sized based on total contributing area.

16.5.2.6 Cut and Fill Slopes

Cut and fill slopes shall be designed and constructed to minimize erosion. Consideration shall be given to the length and steepness of the slope, the soil type, upslope drainage area, groundwater conditions and other applicable factors. The following guidelines are provided to aid site planners and plan reviewers in developing an adequate design:

- Roughened soil surfaces are generally preferred to smooth surfaces on slopes.
- Diversions shall be constructed at the top of long, steep slopes that have significant drainage areas above the slope. Diversions or terraces may also be used to reduce slope length.
- Concentrated stormwater shall not be allowed to flow down cut or fill slopes unless contained within an adequate temporary or permanent channel, flume or slope drain structure.
- Wherever a slope face crosses a water seepage plane that endangers the stability of the slope, adequate subsurface drainage or other protection shall be provided.

16.5.2.7 Waterways and Outlets

All on-site stormwater conveyance channels shall be designed and constructed to withstand the expected velocity of flow from a 2-yr frequency storm with minimum erosion. Stabilization adequate to minimize erosion shall also be provided at the outlets of all pipes and paved channels.

16.5.2.8 Inlet Protection

All storm drain inlets that are made operable during construction shall be protected so that sediment-laden water will not enter the conveyance system without first being filtered or otherwise treated to remove sediment.

16.5.2.9 Crossing Watercourses

- Construction vehicles should be kept out of watercourses as possible. Where in-channel work is necessary, precautions shall be taken to stabilize the work area during construction to minimize erosion. The channel (including bed and banks) shall always be restabilized immediately after in-channel work is completed.

- Where an active (wet) watercourse must be crossed by construction vehicles regularly during construction, a temporary stream crossing shall be provided.

16.5.2.10 Removal and Disposal of Erosion Control Measures

All temporary erosion and sediment control measures shall be disposed of within 30 d after final site stabilization is achieved or after the temporary measures are no longer needed. Trapped sediment and other disturbed soil areas resulting from the disposition of temporary measures shallhave sediment removed and properly disposed and then be permanently stabilized to prevent further erosion and sedimentation.

16.5.2.11 Maintenance

All temporary and permanent erosion and sediment control practices shall be inspected weekly and after a rainfall event of 0.5 inches or grater, and maintained and repaired as needed to assure continued performance of their intended function.

16.6 CONTROL MEASURES AND PRACTICES

16.6.1 <u>Introduction</u>

Following is a discussion of the commonly used erosion and sediment control practices with specific emphasis on application control through one or a combination of established use limitations, design details or construction specifications.

16.6.2 <u>Vegetation</u>

Vegetative filter strips may be used to remove suspended solids from sheet flow runoff but are unacceptable for controlling erosion and sedimentation from concentrated flows. Filter strips may be used to control suspended solids on areas with slopes up to 12% and with slope lengths up to 165 ft. UDOT's seeding window is as follows: Region Landscape Architects provide seeding schedule based on the project location.

<u>Use Limitations</u>

- Permanent seeding is also appropriate for final vegetative cover establishment during acceptable growing seasons.

- Sodding is preferable for use in areas requiring additional protection from concentrated flow, such as grassed swales and waterways and storm drain inlets. Sodding may also be appropriate when an immediate aesthetic effect is desired.

- Mulching should be used with all seeding operations to provide temporary protection during adverse growing seasons and to temporarily stabilize disturbed areas. Typical mulching material includes straw, hay and wood chips.

<u>Construction Guidelines</u>

Seed bed preparation is an important consideration for all vegetative control measures. Soil characteristics (e.g., depth to rock, pH, fertility, moisture) should all be evaluated during plant selection. The local NRCS office may also provide guidance. The erosion and sediment control plan should clearly specify soil-preparation requirements for the project site. Erosion and sediment control facilities may not be considered complete until suitable vegetative cover is established.

16.6.3 <u>Temporary Slope Drain</u>

A flexible or rigid conduit, used before permanent drainage structures, is installed to convey concentrations of runoff from the top to bottom of disturbed slopes. See Figure 16-1.

16.6.3.1 Use Limitations

- Maximum drainage area allowed for each slope drain is 0.5 ac.
- Open-chute drains shall be used only on straight alignment.
- Slope drains shall be placed only on well-compacted stable slopes.

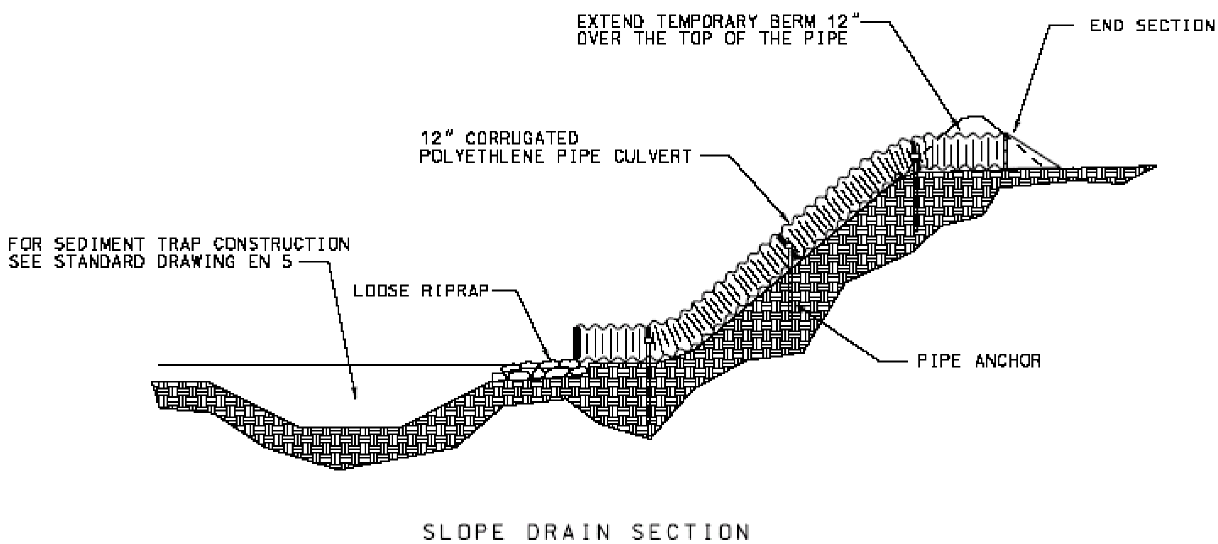


FIGURE 16-1 — Cross Section of Temporary Slope Drain

Source: Reference *(14)*.

16.6.3.2 Design Detailing

No design detailing is required for standard size. Construction Guidelines

- 12-in nominal minimum pipe size.
- The slope drain shall consist of heavy-duty material designed and suitable for the purpose.
- Slope drain sections shall be securely fastened together and have watertight fittings.
- Soil around and under the entrance section shall be hand compacted in 0.5-ft lifts to prevent saturation and pipe failure.
- The outlet of the drain shall be protected to prevent erosion.

16.6.4 Straw Bale Barrier

A straw bale barrier is a temporary sediment barrier consisting of a row of entrenched and anchored straw bales. See Figure 16-2. Baled straw barriers are the most commonly used types of barriers.

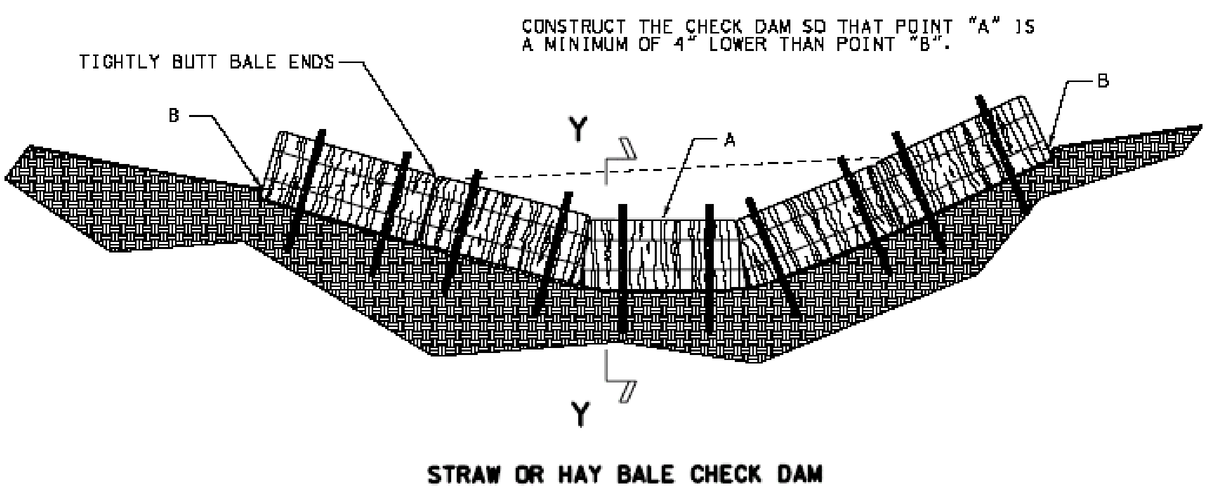


FIGURE 16-2 — Straw Bale Barrier in Drainageway

Source: Reference *(14)*.

16.6.4.1 Use Limitations

- Size of the drainage area is no greater than 0.25 ac per 100 ft of barrier length.

- Maximum slope length behind the barrier is 100 ft.
- Maximum slope gradient behind the barrier is 50%.
- Use in minor swales or ditches where the maximum contributing drainage area is no greater than 1 ac.
- Use where effectiveness is required for less than 3 months.
- Under no circumstances should straw bale barriers be constructed in active streams or in swales where there is the possibility of a washout.
- Should be used only in areas of sheet flow or very low flow.
- Do not use where the control of sediment is critical or in high-risk areas.
- Do not use where it cannot be entrenched as required and firmly anchored. Useful life of the baled straw barrier is relatively short, and the barrier may have to be replaced one or more times during construction.
- Often, will need repair or replacement after one significant runoff event.

16.6.4.2 Design Detailing

No formal design is required.

16.6.4.3 Construction Guidelines

16.6.4.3.1 Sheet Flow Applications

- Bales shall be placed in a single row, lengthwise on the contour, with ends of adjacent bales tightly abutting.
- All bales shall be either wire-bound or string-tied. Straw bales shall be installed so that bindings are oriented around the sides rather than along the tops and bottoms of the bales (to prevent deterioration of bindings).
- The barrier shall be entrenched and backfilled. A trench shall be excavated the width of a bale and the length of the proposed barrier to a minimum depth of 4 in. After the bales are staked and chinked, the excavated soil shall be backfilled against the barrier. Backfill soil shall conform to the ground level on the downhill side and shall be built up to 4 in against the uphill side of the barrier.
- Each bale shall be securely anchored by at least two stakes driven toward the previously laid bale to force the bales together. Stakes shall be driven into the ground to securely anchor the bales.
- The gaps between bales shall be chinked (filled by wedging) with straw to prevent water from escaping between the bales. Loose straw scattered over the area immediately uphill from a straw barrier tends to increase barrier efficiency.
- Inspection shall be frequent and repair or replacement shall be made promptly as needed.

- Straw bale barriers shall be removed when they have served their usefulness but not before the upslope areas have been permanently stabilized.

16.6.4.3.2 Channel Flow Applications

- Bales shall be placed in a single row, lengthwise, oriented perpendicular to the contour, with ends of adjacent bales tightly abutting one another.

- The remaining steps for installing a straw bale barrier for sheet flow applications apply, with the following addition.

- The barrier shall be extended to such a length that the bottoms of the end bales are higher in elevation than the top of the lowest middle bale to assure that sediment-laden runoff will flow either through or over the barrier but not around it.

16.6.5 Channel Lining

One means of reducing erosion during highway construction and operation is through the use of properly designed linings in drainage channels. Linings may be rigid (e.g., portland cement, asphaltic concrete) or flexible (e.g., vegetation) fabric liners or rock riprap. Flexible linings of erosion-resistant vegetation and rock riprap should be used where feasible. Where vegetation is chosen as the permanent channel lining, it may be established by seeding or sodding. Installation by seeding usually requires protection by one of a variety of temporary lining materials until the vegetation becomes established. Following are some examples of vegetated and riprap channel linings.

16.6.5.1 Use Limitations

Flexible linings are generally less expensive to install than rigid linings, provide a safer roadside and have self-healing qualities that reduce maintenance costs. They also permit infiltration and exfiltration, have a natural appearance, especially after vegetation is established, and provide a filtering media for runoff contaminants. Vegetative and rock riprap liners provide less improvement in conveyance over natural conditions, and the resultant acceleration of flow volume and peak is less than with rigid liners.

Flexible linings have the disadvantage of being limited in the depth of flow that they can accommodate without erosion occurring. As a result, the channel may provide a low capacity for a given cross sectional area when compared to a rigid lining. Also, limited right-of-way, unavailability of rock or the inability to establish vegetation may preclude the use of flexible linings. In these instances, rigid linings may be the only alternative.

Rigid linings are generally quite smooth, so that they have a high capacity for a given cross sectional area due to low hydraulic resistance, and thus produce a high-flow velocity. When properly designed and constructed, rigid linings will prevent erosion in steep or difficult channels where other linings cannot be used. They may also be used in areas where the channel width is restricted, because steep sidewall slopes may be constructed. So long as the rigid lining is intact, the underlying soil is completely protected upon construction of the lining.

However, rigid linings also have a number of inherent disadvantages. They are expensive to construct and maintain, have an unnatural appearance, prevent or reduce natural infiltration and contribute to high velocities and scour at the downstream end of the lining unless roughness elements are added to slow the flow. Many rigid linings are destroyed due to slow undercutting of the lining, channel headcutting or hydrostatic pressure behind the channel walls or floor.

Following is a brief description of some channel linings that can be used for erosion control:

JUTE MESH. Jute mesh is a mat lining woven of jute yarn that varies from 1/8 in to 1/4 in in diameter. The mat weighs approximately 0.80 lb/yd^2, with openings approximately 3/8 in × 3/4 in. It can be used with or without straw underlay.

EXCELSIOR MAT. Excelsior mat is composed of 0.80 lb/yd^2 of excelsior (dried, shredded wood) covered with a fine paper net covering. The paper net, reinforced along the edges, has an opening size of approximately 1/2 in x 2 in. The mat is held in place by steel pins or staples at the rate of 5 staples per 4 ft of mat, with two staples along each side and one in the middle.

STRAW/COCONUT FIBER MAT. The lining consists of straw applied at a rate of 3 tons/ac (1.25 lbs/yd^2)). The straw/cocnut is covered with 2 netting top and bottom.

TURF REINFORCEMENT MATS. These mats are of three-dimensional structures of entangled nylon monofilaments, melt-bonded at their intersections. The mat shall be capable of maintaining its shape and be highly resistant to environmental and ultraviolet degradation.

ROCK RIPRAP. Channels can be stabilized by using rock riprap along the channel bottom and sides where erosion would be anticipated. See Figure 16-3. A filter blanket consists of one or more layers of graded material or a geotech fabric can be placed on the bank before placing the riprap to prevent highly erodible bank material from passing through the riprap protection. The thickness and gradation of the filter blanket or specification of the geotech fabric should be included on the plans. Types of riprap can include the following:

- *Dumped Riprap* — Dumped riprap consists of stone dumped in place to form a well-graded mass with a minimum of voids.

- *Wire-Enclosed Riprap* — Wire-enclosed riprap consists of mats or baskets fabricated from wire mesh, filled with stone, connected together and anchored to the slope. Details of construction may differ depending upon the degree of exposure and the service, whether used for revetment or used as a toe protection for the other types of riprap.

- *Concrete-Slab Riprap* — Concrete-slab riprap consists of concrete, plain or reinforced, poured in place or precast concrete blocks.

- *Grouted Riprap* — Grouted riprap consists of riprap with all or part of the interstices filled with portland cement mortar.

16.6.5.2 Design Detailing

RIGID CHANNEL LININGS. For rigid channel linings, such as concrete or soil cement, there is no maximum permissible depth for the flow velocities normally encountered in highway drainage work, because no erosion can occur. Thus, the maximum flow depth is based only on the freeboard requirement for the channel. See the Bank Protection Chapter for more design detailing related to rigid channel linings.

FLEXIBLE CHANNEL LININGS. For design detailing, the user is referred to the Channels and Bank Protection Chapters of this *Manual* and Reference *(6)*.

16.6.6 Outlet Protection

The outlets of pipes and structurally lined channels are points of critical erosion potential. To prevent scour at stormwater outlets, a flow-transition structure is needed that will absorb the initial impact of the flow and reduce the flow velocity to a level that will not erode the receiving channel or area.

The most commonly used device for outlet protection is a structurally lined apron. These aprons are generally lined with riprap, grouted riprap or concrete. They are constructed at a zero grade for a distance that is related to the outlet pipe diameter. Figure 16-4 gives some general guidance for a standardized apron design. See Table 16-1 for stone size specifications. Figure 16-5 provides examples of structures used for outlet protection by dissipating energy. Where flow is excessive for the economical use of an apron, excavated stilling basins or other alternative structures may be used.

Table 16-2 gives the permissible velocity recommendations that are provided for guidance in the determination of outlet protection needs.

Design Detailing can be found in the Energy Dissipator Chapter of this *Manual* or in HEC 14 *(5)* and Reference *(13)*.

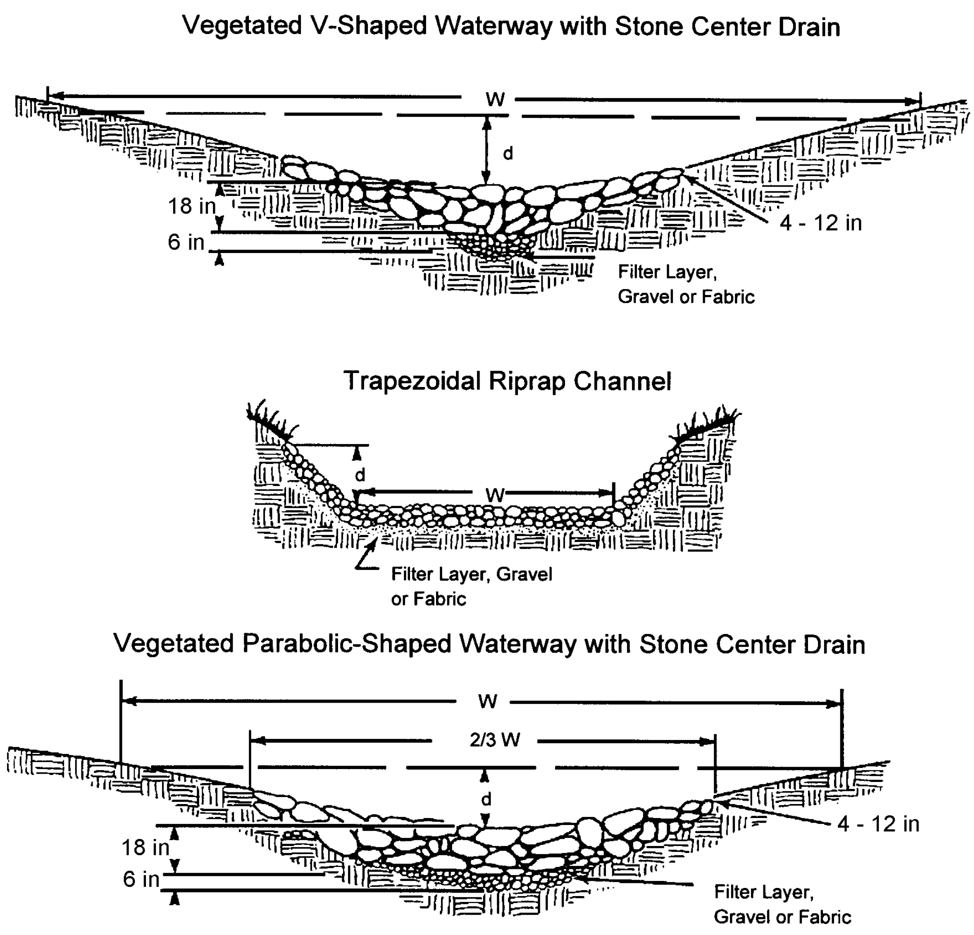


FIGURE 16-3 — Riprap Channel Cross Section

Source: Reference *(10)*.

16.6.7 <u>Diversion</u>

A diversion channel is a channel constructed across a slope with a supporting ridge on the lower side to reduce the slope length and to intercept and divert stormwater runoff to stabilized outlets at non-erosive velocities. Diversions are used where:

- runoff from higher areas may damage property, cause erosion or interfere with the establishment of vegetation on lower areas;
- surface and/or shallow subsurface flow is damaging upland slopes; or
- the slope length needs reduction to minimize soil loss.

Figures 16-6 and 16-7 illustrate the use of diversions.

16.6.7.1 Design Detailing

In most instances, diversions are constructed using a standard design or sized for site flow conditions.

<u>Location</u>

Diversion location should be determined by considering outlet conditions, topography, land use, soil type, length of slope, seepage planes (where seepage is a problem), and the development layout.

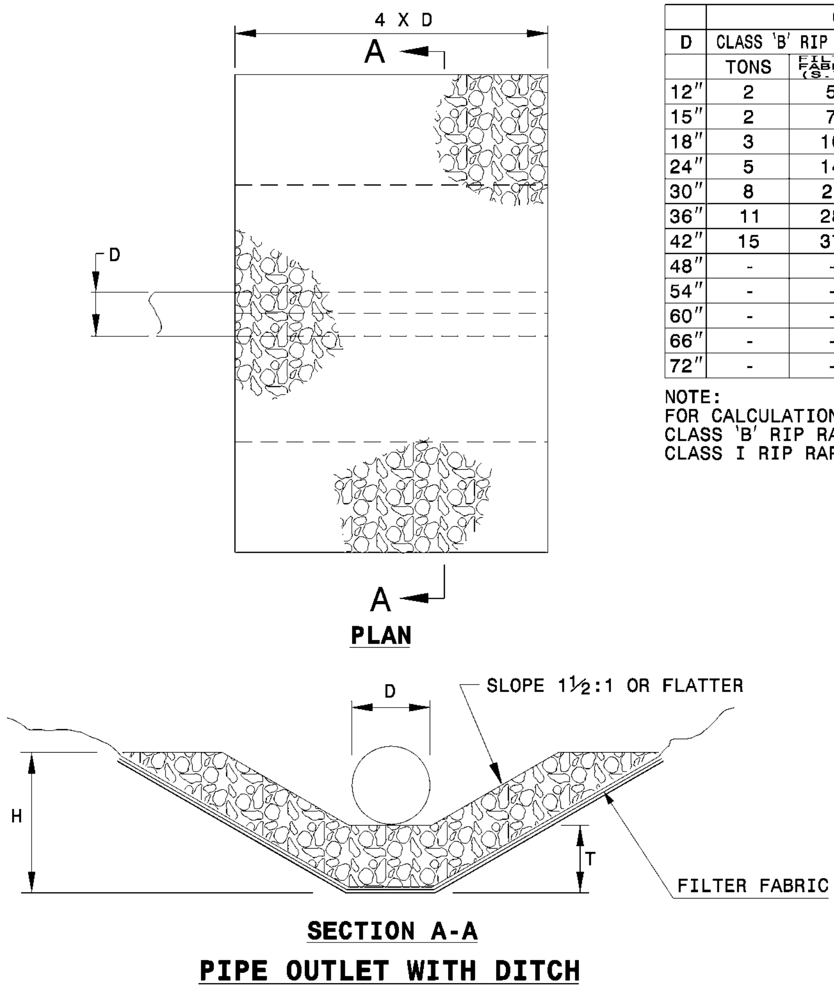
TABLE 16-1 — Stone and Fabric Specification

Class B	Stone shall be of a hard, durable nature and range in size from 5 in to 15 in. Although no specific gradation is required, the various sizes of stone shall be equally distributed within the required size range.
Class I	Stone shall vary in weight from 5 lbs to 200 lbs. At least 30% of the total weight of the riprap shall be in individual pieces weighing a minimum of 60 lbs. Not more than 10% of the total weight of the riprap may be in individual pieces weighing less than 15 lbs each.

Source: Reference *(9)*

<u>Capacity</u>

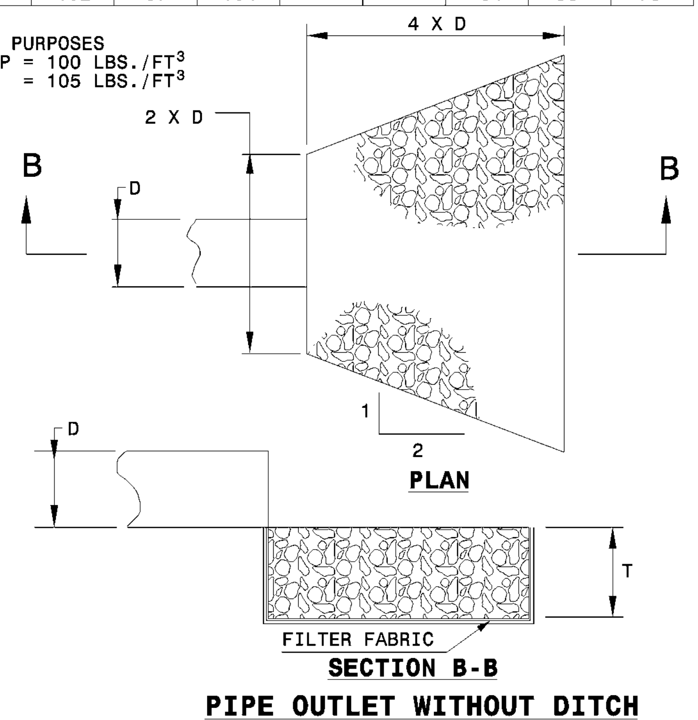
- The diversion channel shall have a minimum capacity to carry the runoff expected from a 10-yr frequency storm with a freeboard of at least 0.3 ft.
- Diversions designed to protect homes, schools, industrial buildings, roads, parking lots and comparable high-risk areas, and those designed to function in connection with other structures, shall have sufficient capacity to carry peak runoff expected from a storm frequency consistent with the hazard involved.



H= RIP RAP TO TOP OF PIPE (MAX. H = D + T)
T= 15″ CLASS I RIP RAP, UNLESS OTHERWISE SHOWN ON PLANS
T= 12″ CLASS 'B' RIP RAP, UNLESS OTHERWISE SHOWN ON PLANS

	OUTLET W/DITCH					OUTLET W/O DITCH				
D	CLASS 'B' RIP RAP		CLASS I RIP RAP			CLASS 'B' RIP RAP		CLASS I RIP RAP		
	TONS	FILTER FABRIC (S.Y.)	S.Y.	TONS	FILTER FABRIC (S.Y.)	TONS	FILTER FABRIC (S.Y.)	S.Y.	TONS	FILTER FABRIC (S.Y.)
12″	2	5	5	2	5	1	4	2	1	4
15″	2	7	7	3	7	1	5	3	2	6
18″	3	10	9	4	10	2	7	4	2	8
24″	5	14	15	7	15	3	11	7	4	12
30″	8	21	21	11	22	5	16	11	7	17
36″	11	28	29	15	30	7	22	16	10	23
42″	15	37	39	20	39	10	28	22	13	30
48″	-	-	49	26	50	-	-	28	17	38
54″	-	-	60	33	62	-	-	36	21	47
60″	-	-	73	40	75	-	-	44	26	56
66″	-	-	87	48	89	-	-	54	32	67
72″	-	-	102	57	104	-	-	64	38	78

NOTE:
FOR CALCULATION PURPOSES
CLASS 'B' RIP RAP = 100 LBS./FT^3
CLASS I RIP RAP = 105 LBS./FT^3



Source: Reference *(8)*.

FIGURE 16-4 — Riprap Outlet Protection

Channel Design

The diversion channel may be parabolic, trapezoidal or V-shaped.

Ridge Design

The supporting ridge cross-section shall meet the following criteria:

- The side slopes shall be no steeper than 1V:2H.
- The width at the design water elevation shall be a minimum of 4 ft.
- The minimum freeboard shall be 0.3 ft.

Include a 10% settlement factor.

16.6.7.2 Construction Guidelines

Outlet

Diversions shall have adequate outlets that will convey concentrated runoff without erosion.

Stabilization

- Unless otherwise stabilized, the ridge and channel shall be seeded and mulched within 14 d of installation.
- Disturbed areas draining into the diversion shall be seeded and mulched prior to or at the same time the diversion is constructed.

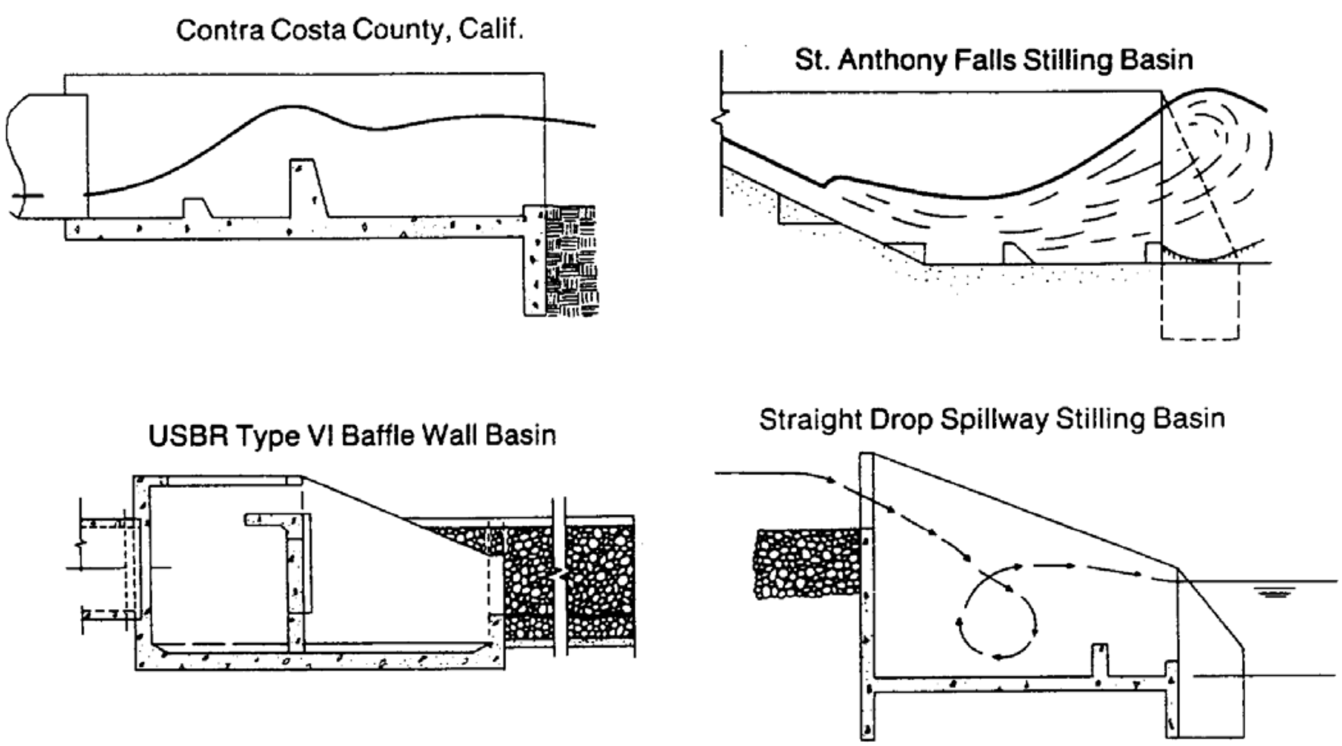


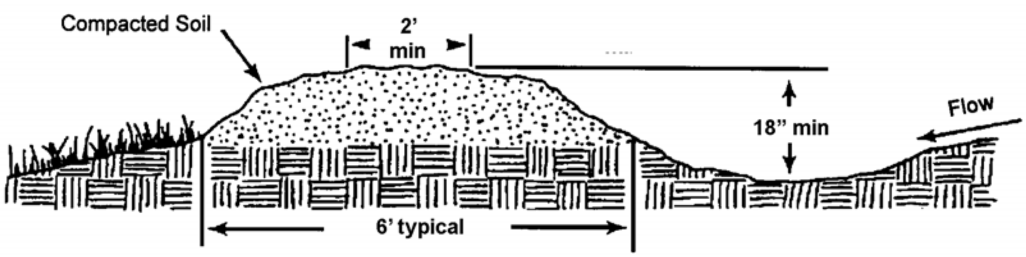
FIGURE 16-5 — Alternative Structures For Energy Dissipation

Source: Reference *(10)*.

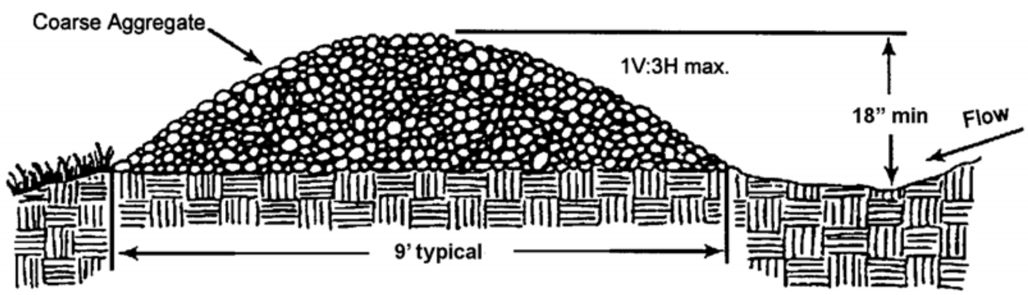
TABLE 16-2 — Permissible Velocities

Earth Linings	
Soil Types	Permissible Veloctiy (ft/s)
Fine Sand (noncolloidal)	2.5
Sandy Loam (noncolloidal)	2.5
Silt Loam (noncolloidal)	3.0
Ordinary Firm Loam	3.5
Fine Gravel	5.0
Stiff Clay (very colloidal)	5.0
Graded, Loam to Cobbles (noncolloidal)	5.0
Graded, Silt to Cobbles (colloidal)	5.5
Alluvial Silts (noncolloidal)	3.5
Alluvial Silts (colloidal)	5.0
Coarse Gravel (noncolloidal)	6.0
Cobbles and Shingles	5.5
Shales and Hard Pans	6.0

Source: Reference *(11)*.

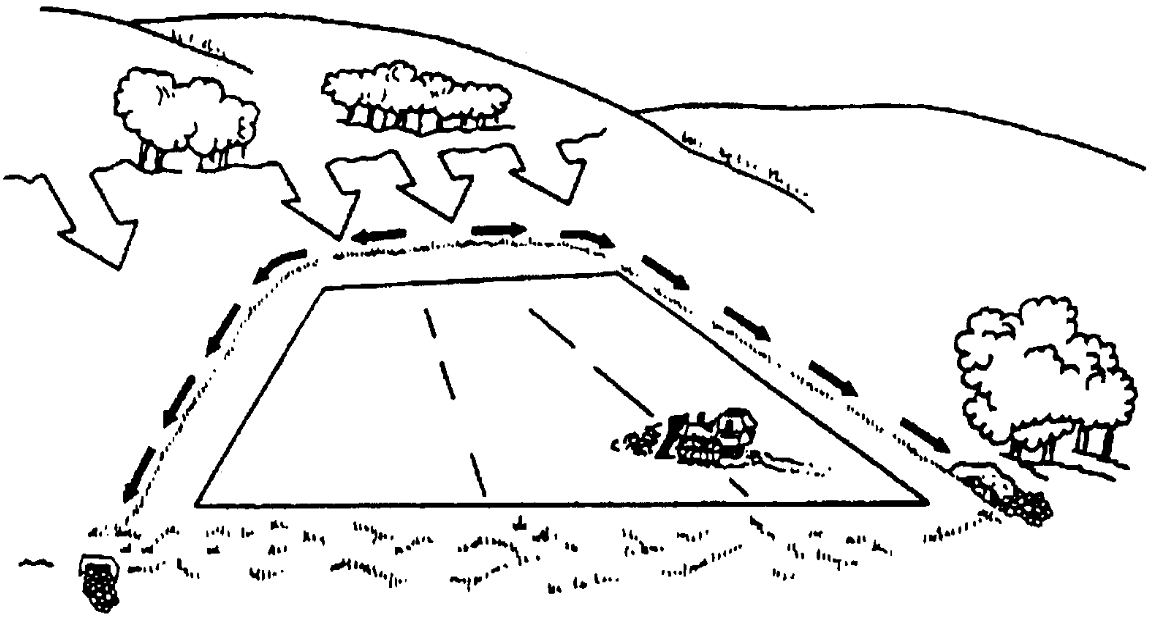


Temporary Earthen Diversion Dike



Temporary Gravel Diversion Dike for Vehicle Crossing (Modified from Va SWCC)

FIGURE 16-6 — Use Of Temporary Diversions



Perimeter dikes prevent surface runoff from entering construction sites.

FIGURE 16-7 — Use of Perimeter Dikes As Diversions

Source: Reference *(10)*.

General Considerations

- All trees, brush, stumps, obstructions and other objectionable material shall be removed and disposed of so as not to interfere with the proper functioning of the diversion.
- The diversion shall be excavated or shaped to line, grade and cross section as required to meet the criteria specified, and free of irregularities that will impede flow.
- Fills shall be compacted as needed to prevent unequal settlement that would cause damage in the completed diversion.
- All earth removed and not needed in construction shall be spread or disposed of so that it will not interfere with the functioning of the diversion.
- Permanent stabilization of disturbed areas shall be done in accordance with the applicable standards and specifications.

16.6.8 Brush Barrier

A brush barrier is a temporary sediment barrier that is used to intercept and retain sediment from disturbed areas of limited extent, preventing sediment from leaving the site. Brush barriers are constructed at the time of clearing and grubbing and consist of brush, limbs, root mat, weeds, vines, soil, rock and unmerchantable timber. Where applicable, the brush barrier shall be constructed at the perimeter of a disturbed area using the residue materials available from clearing and grubbing the site.

16.6.8.1 Use Limitation

- Should be located within 500 ft of source of material.
- Should be used only in areas of sheet or very low flow.
- Should not be used in a developed area where they could be a visual or other nuisance problem.

16.6.8.2 Construction Guidelines

- Height of a brush barrier shall be 3 ft minimum.
- The width of a brush barrier shall be a minimum of 5 ft at its base. The sizes of brush barriers may vary considerably based upon the amount of material available and judgment of designer.
- The barrier shall be constructed by piling brush, stone, root mat and other material from the clearing process into a mounded row on the contour

Source: Reference *(12)*.

- The filter fabric shall be cut into lengths sufficient to lay across the barrier from its upslope base to just beyond its peak. Where joints are necessary, the fabric shall be spliced together with a minimum 12-in overlap and securely sealed.
- A trench shall be excavated 4 in wide and 4 in deep along the length of the barrier and immediately uphill from the barrier.
- The lengths of filter fabric shall be draped across the width of the barrier with the uphill edge placed in the trench and the edges of adjacent pieces overlapping each other.
- The filter fabric shall be secured in the trench with stakes set approximately 3 ft on center.
- The trench shall be backfilled and the soil compacted over the filter fabric.
- Set stakes into the ground along the downhill edge of the brush barrier, and anchor the fabric by tying twine from the fabric to the stakes.

16.6.9 Silt Fence

A silt fence is a temporary sediment barrier consisting of a filter fabric stretched across and attached to supporting posts and entrenched. The silt fence is a temporary linear filter barrier constructed of synthetic filter fabric and. This barrier is used:

- for perimeter control;
- for intercepting and detaining small amounts of sediment from disturbed areas during construction operations to prevent sediment from leaving the site;
- for decreasing the velocity of sheet flows and low level channel flows;

- in high-risk areas, as adjacent to streams, wetlands, reservoirs, lawns, etc.;
- as continual barriers at the toe of fill where ground slopes away;
- around median and yard inlets as applicable; and
- behind curb and gutter to prevent silting of the pavement.

16.6.9.1 Use Limitations

- Only use where the size of the drainage areas is no more than 0.25 ac per 100 ft of silt fence length; the maximum slope length behind the barrier is 100 ft; and the maximum gradient behind the barrier is 50% (1V:2H).
- Under no circumstances should silt fences be constructed in live streams or in swales or ditch lines where flows are likely to exceed 1 ft^3/s.
- On steep slopes, care should be given to placing alignment of fence perpendicular to the general direction of the flow.

16.6.9.2 Design Detailing (see Figure 16-8)

- No formal design is required.

Silt fences are limited to sites where only sheet or overland flows are expected. They normally cannot filter the volumes of water generated by channel flows, and many of the fabrics do not have sufficient structural strength to support the weight of water ponded behind the fence line. Their expected usable life is 5 months.

16.6.9.3 Construction Guidelines

Materials

See UDOT material specs for fence material requirements.

  - Test – ASTM D4595
  - Requirements reduced by 50% after 6 months.

Synthetic filter fabric shall contain ultraviolet ray inhibitors and stabilizers to provide a minimum of 6 months of expected usable construction life at a temperature range of -0^{o} F to 120^{o} F.

- Posts for silt fences shall be either 2-in diameter wood or 1.33 lbs/ft of steel with a minimum length of 5 ft. Steel posts shall have projections for fastening wire to them.
- The height of a silt fence shall not exceed 3 ft (higher fences may impound volumes of water sufficient to cause failure of the structure).

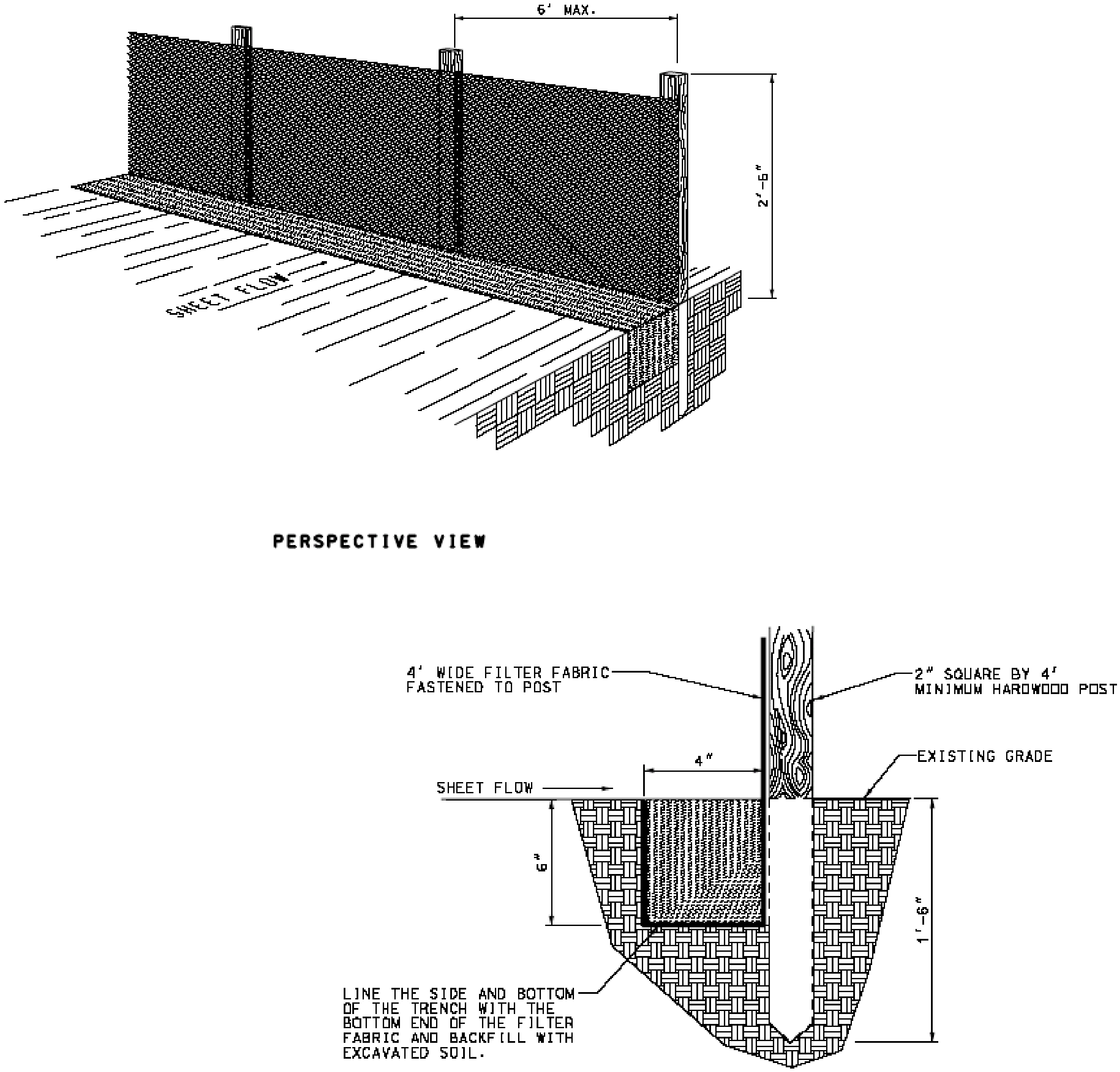


FIGURE 16-8 — Installation of Silt Fence

Source: Reference *(14)*.

- The filter fabric shall be purchased in a continuous roll cut to the length of the barrier to avoid the use of joints. Where joints are necessary, filter cloth shall be spliced together only at a support post, with a minimum 6-in overlap, and securely sealed.

- Posts shall be spaced a maximum of 6 ft apart at the barrier location and driven securely into the ground minimum of 2 ft.

- A trench shall be excavated approximately 6 in wide and 6 in deep along the line of posts and upslope from the barrier.

- The standard-strength filter fabric shall be stapled or wired to the fence, and 8 in of the fabric shall be extended into the trench. The fabric shall not extend more than 3 ft above the original ground surface. Filter fabric shall not be stapled to existing trees.

- Where extra-strength filter fabric and closer post spacings are used, the wire-mesh support fence may be eliminated. In such a case, the filter fabric is stapled or wired directly to the posts with all other provisions of the above item applying.

- The trench shall be backfilled and the soil compacted over the filter fabric.

- Silt fences should be removed when they have served their useful purpose, but not before the upslope area has been permanently stabilized.

16.6.10 <u>Check Dams</u>

Check dams are small temporary dams constructed across a swale or drainage ditch, which reduce the velocity of concentrated stormwater flows, thereby reducing erosion of the swale or ditch. See Figure 16-9. This practice also traps small amounts of sediment generated in the ditch itself. However, this is not a sediment trapping practice and should not be used as such.

16.6.10.1 Use Limitations

This practice is limited to use in small open channels that drain 10 ac or less. It should not be used in an active stream. Some specific applications include the following:

- temporary ditches or swales that, because of their short length of service, cannot receive a non-erodible lining but still need some protection to reduce erosion;

- permanent ditches or swales that for some reason cannot receive a permanent non-erodible lining for an extended period of time; oreither temporary or permanent ditches or swales that need protection during the establishment of grass linings.

Other limitations would include the following:

- Do not use where high flows or high velocities are expected.

- In locating the check dam, consider the effects and the reach of the impounded water and sediment.

- Storm flows across a deteriorated check dam can result in the loss of the structure and the washout of the accumulated sediment.

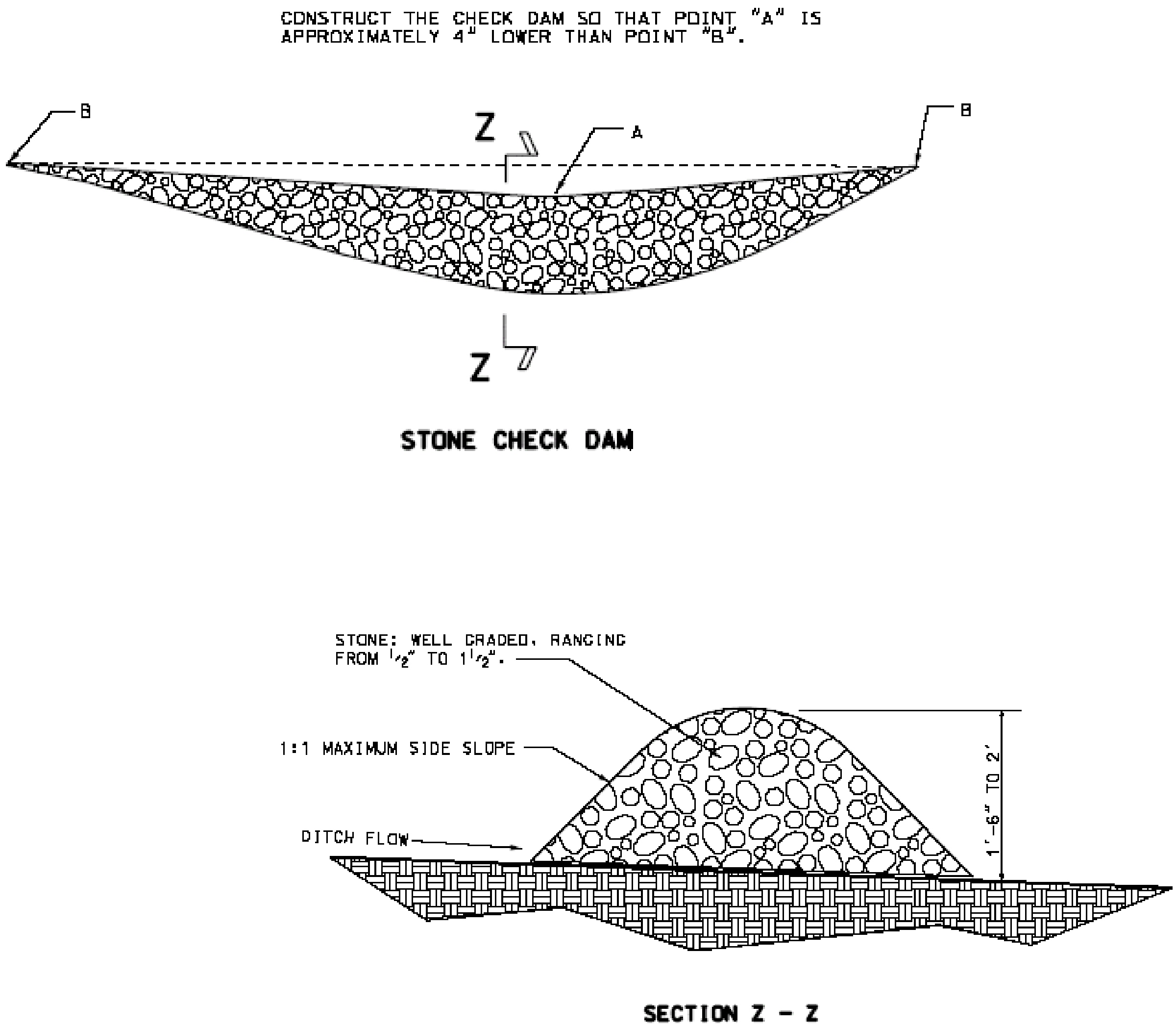


FIGURE 16-10 — Stone Check Dam

Source: Reference *(14)*.

16.6.10.2 Design Detailing

The drainage area of the ditch or swale being protected should not exceed 10 ac. The maximum height of the check dam should be 2 ft. The center of the check dam shall be at least 6 in lower than the outer edges. If used in combination, the maximum spacing between the dams should be such that the toe of the upstream dam is at the same elevation as the top of the downstream dam.

16.6.10.3 Construction Guidelines

- Stone check dams should be constructed of 2-in to 3-in stone. Hand or mechanical placement will be necessary to achieve complete coverage of the ditch or swale and to ensure that the center of the dam is lower than the edges.

Sediment Removal

- Although this practice is not intended to be used primarily for sediment trapping, some sediment will accumulate behind the check dams. Sediment should be removed from behind the check dams when it has accumulated to one-half of the original height of the dam.

Removal

- Check dams should be removed when their useful life has been completed. In temporary ditches and swales, check dams should be removed and the ditch filled in when it is no longer needed. In permanent structures, check dams should be removed where a permanent lining can be installed. For grass-lined ditches, check dams should be removed when the grass has matured sufficiently to protect the ditch or swale. The area beneath the check dams should be seeded and mulched immediately after they are removed.

16.6.11 Temporary Sediment Trap

This is a small, temporary ponding area formed by constructing an earthen embankment with a control outlet, generally constructed of rock or gravel. See Figure 16-10. The purpose is to detain sediment-laden runoff from small, disturbed areas long enough to allow the majority of the sediment to settle out.

16.6.11.1 Use Limitations

- Use for drainage areas of 5 ac or less.
- Use where the sediment trap will be needed no longer than 18 months. The maximum useful life is 18 months.
- The sediment trap may be constructed either independently or in conjunction with a temporary diversion dike.
- Sediment traps should be used only for small drainage areas. If the contributing drainage area is greater than 5 ac, sediment basins shall be used.
- Sediment shall be periodically removed from the trap. Plans should detail how this sediment is to be disposed of, such as by use in fill areas on-site or removal to an approved off-site dump.
- Sediment traps, along with other perimeter controls, shall be installed before any land disturbance occurs in the drainage area.

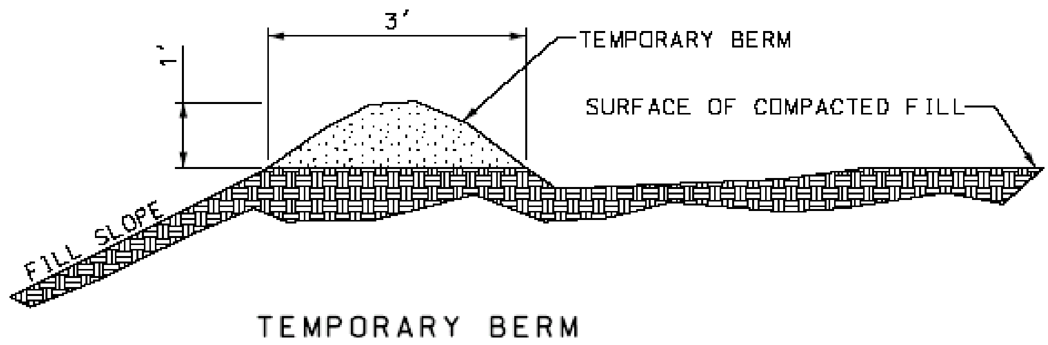


FIGURE 16-11 — Temporary Sediment Trap

Source: Reference *(14)*.

16.6.11.2 `Design Detailing

Trap Capacity

The sediment trap shall have an initial storage volume of 67 yd^3 per acre of drainage area, measured from the low point of the ground to the crest of the gravel outlet. Sediment should be removed from the basin when the volume is reduced by one-half.

For a natural basin, the volume may be approximated as follows:

$$V = (0.4)(A)(D) \tag{16.1}$$

where: V = the storage volume, ft^3

A = the surface area of the flooded area at the crest of the outlet, ft^2

D = the maximum depth, measured from the low point in the trap to the crest of the outlet, ft

Excavation

If excavation is necessary to attain the required storage volume, side slopes should be no steeper than 1V:2H.

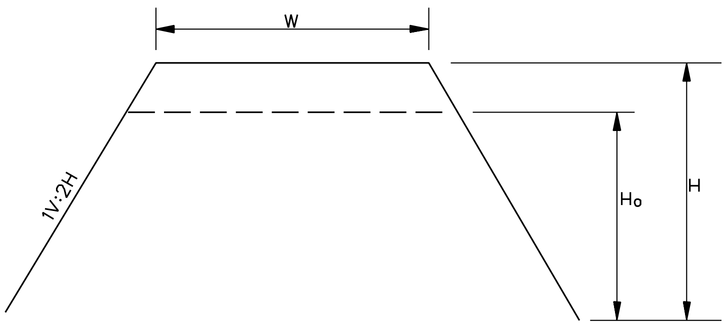
Outlet

The outlet for the sediment trap generally consists of a crushed stone section of the embankment located at the low point in the basin. The minimum length of the outlet crest shall be 15 ft times the ac of the drainage area. The crest of the outlet shall be at least 1 ft below the top of the embankment to ensure that the flow will travel over the stone and not the embankment.

Embankment Cross Section

The maximum height of the sediment trap embankment shall be 5 ft as measured from the low point. Minimum top widths (W) and outlet heights (H_o) for various embankment heights (H) are shown in Table 16-3. Side slopes of the embankment shall be 1V:2H or flatter.

TABLE 16-3 — Minimum Top Width (W) Required For Sediment Trap Embankments According To Height of Embankment (ft)



H_o (ft)	H (ft)	W (ft)
0.5	1.5	2.0
1.0	2.0	2.0
1.5	2.5	2.5
2.0	3.0	2.5
2.5	3.5	3.0
3.0	4.0	3.0
3.5	4.5	4.0
4.0	5.0	4.5

Source: Modified From Reference *(4).*

Removal

Sediment traps shall be removed after the contributing drainage area is stabilized. Plans should show how the site of the sediment trap is to be graded and stabilized after removal.

16.6.11.3 Construction Guidelines

- The area under the embankment shall be cleared, grubbed and stripped of any vegetation and root mat. To facilitate cleanout, the pool area should be cleared.
- Fill material for the embankment shall be free of roots or other woody vegetation, organic material, large stones and other objectionable material. The embankment should be compacted in 8-in layers by traversing with construction equipment.
- The earthen embankment shall be seeded with temporary or permanent vegetation within 15 d of construction.
- Construction operations shall be performed so that erosion and water pollution are minimized.
- The structure shall be removed and the area stabilized when the upslope drainage area has been stabilized.
- All cut and fill slopes shall be 1V:2H or flatter.

16.6.12 Temporary Sediment Basin

A storage area is provided to detain sediment-laden runoff from disturbed areas long enough for the majority of the sediment to settle out. The facility is a temporary basin with a controlled stormwater release structure, formed by constructing an embankment of compacted soil across a drainageway.

16.6.12.1 Use Limitations

Temporary sediment basins can be used below disturbed areas generally greater than 5 ac. There shall be sufficient space and appropriate topography for the construction of a temporary impoundment. These structures are limited to a useful life of 18 months, unless they are designed as permanent ponds by a qualified professional engineer.

16.6.12.1.1 Effectiveness

Sediment basins are at best only 70% to 80% effective in trapping sediment that flows into them. Therefore, they should be used in conjunction with erosion control practices such as temporary seeding, mulching, diversion dikes, etc., to reduce the amount of sediment flowing into the basin.

16.6.12.1.2 Location

To improve the effectiveness of the basin, it should be located to intercept the largest possible amount of runoff from the disturbed area. The best locations are generally low areas and natural drainageways below disturbed areas. Drainage into the basin can be improved by the use of diversion dikes and ditches. The basin shall not be located in a live stream but should be located to trap sediment-laden runoff before it enters the stream. The basin should not be located where its failure would result in the loss of life or interruption of use of public utilities or roads.

16.6.12.1.3 Multiple Use

Sediment basins may be designed as permanent structures to remain in place after construction is completed. Where these structures are to become permanent, or if they exceed the size limitations of the design criteria, they shall be designed as permanent ponds by a qualified professional engineer.

16.6.12.2 Design Detailing

16.6.12.2.1 Maximum Drainage Area

Unless the structure is designed as a permanent pond by a professional engineer, the maximum allowable drainage area into the basin shall be 150 ac.

16.6.12.2.2 Basin Capacity

The design capacity of the basin shall be at least 67 ft^3 per acre of drainage area, measured from the bottom of the basin to the crest of the principal spillway (riser pipe). Sediment should be removed from the basin when the volume of the basin has been reduced to 34 ft^3 per acre of drainage area. In no case shall the sediment cleanout level be higher than 1 ft below the top of the riser. The elevation of the sediment cleanout level should be calculated and clearly marked on the riser. A series of small basins has proven to be in some instances more effective than one large basin and may be better adaptable to the highway right-of-way.

Sediment trapping efficiency is primarily a function of sediment particle size and the ratio of basin surface area to inflow rate. Therefore, design the basin to have a large surface area for its volume. Figure 16-12 shows the relationship between the ratio of surface area to peak inflow rate and trap efficiency observed by Barfield and Clark *(3)*.

Sediment basins with an expected life greater than 18 months shall be designed as permanent structures. In these cases, the structure shall be designed by a qualified professional engineer experienced in the design of dams.

16.6.12.2.3 Basin Shape

To improve sediment trapping efficiency of the basin, the effective flow length shall be twice the effective flow width. This basin shape may be attained by properly selecting the site of the basin, by excavation or by the use of baffles.

16.6.12.2.4 Embankment Cross Section

The embankment shall have a minimum top width of 8 ft. The side slopes shall be 1V:2H or flatter. The embankment may have a maximum height of 10 ft if the side slopes are 1V:2H. If the side slopes are 1V:2½H or flatter, the embankment may have a maximum height of 15 ft.

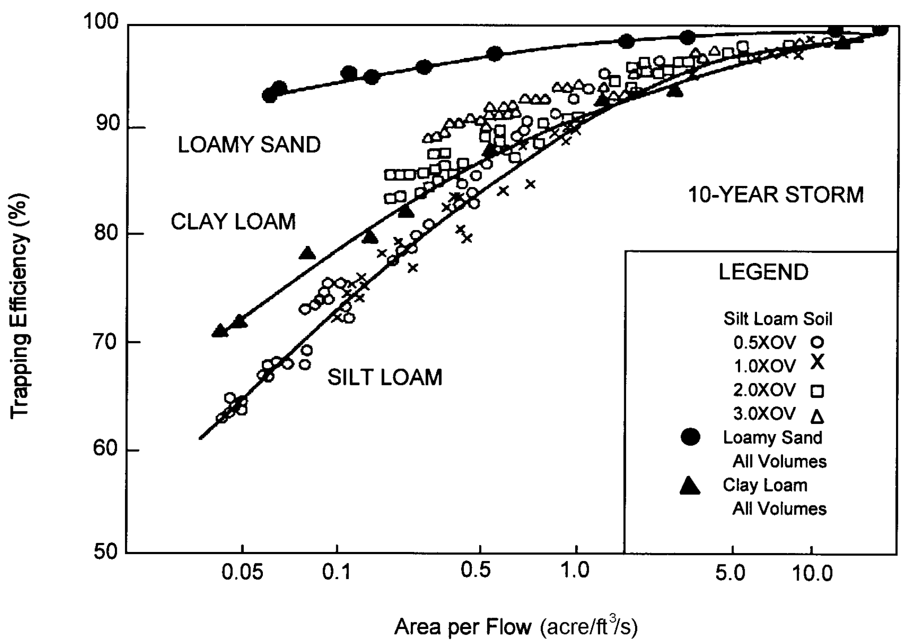


FIGURE 16-12 — Surface Area/Peak Discharge vs. Trap Efficiency

Source: Reference *(3)*.

16.6.12.2.5 Spillway Design

The outlets for the basin may consist of a combination of principal and emergency spillways or a principal spillway alone. In either case, the outlet(s) shall pass the peak runoff expected from the drainage area for a 10-yr storm without damage to the embankment of the basin. Runoff computations shall be based upon the soil cover conditions that are expected to prevail during the life of the basin. To increase the efficiency of the basin, the spillway(s) can be designed to maintain a permanent pool of water.

16.6.12.2.6 Principal Spillway

The principal spillway shall consist of a solid (non-perforated), vertical pipe or box of corrugated metal or reinforced concrete joined by a watertight connection to a horizontal pipe (barrel) extending through the embankment and outletting beyond the downstream toe of the fill. If the principal spillway is used in conjunction with an emergency spillway, the principal spillway shall have a minimum capacity of 0.2 ft^3/s per acre per acre of drainage area when the water surface is at the crest of the emergency spillway. If no emergency spillway is used, the principal spillway shall be designed to pass the entire peak flow expected from a 10-yr storm.

DESIGN ELEVATIONS. If the principal spillway is used in conjunction with an emergency spillway, the crest of the principal spillway shall be a minimum of 1 ft below the crest of the emergency spillway. If no emergency spillway is used, the crest of the principal spillway shall be a minimum of 3 ft below the top of the embankment. In either case, a minimum freeboard of 1 ft shall be provided between the design high water and the top of the embankment.

ANTI-VORTEX DEVICE AND TRASH RACK. A trash rack shall be attached to the top of the principal spillway to prevent floating debris from being carried out of the basin. An anti-vortex device should be considered to improve flow into the spillway.

DEWATERING. At a minimum, provisions shall be made to dewater the basin down to the sediment cleanout elevation. This can be accomplished by providing dewatering in the spillway structure. Dewatering holes shall be no larger than 4 in in diameter. A stone filter will be required around the spillway structure to prevent loss of stored sediment.

BASE. The base of the principal spillway shall be firmly anchored to prevent its floating. If the riser of the spillway is greater than 10 ft in height, computations shall be done to determine the anchoring requirements. At a minimum, a factor of safety of 1.25 shall be used (downward forces = 1.25 × upward forces).

BARREL. The barrel of the principal spillway, which extends through the embankment, shall be designed to carry the flow provided by the riser of the principal spillway with the water level at the crest of the emergency spillway. The connection between the riser and the barrel shall be watertight. The outlet of the barrel shall be protected to prevent erosion or scour of downstream areas.

ANTI-SEEP COLLARS. If the pond is not provided with means for releasing the stored runoff between inflow storms, anti-seep collars (see Figure 16-13) shall be used on the barrel of the principal spillway within the normal saturation zone of the embankment to increase the seepage length by at least 10%, if either of the following two conditions is met:

1. the settled height of the embankment exceeds 10 ft, or
2. the embankment has a low silt-clay content (Unified Soil Class SM or GM).

Anti-seep collars shall be installed within the saturated zone. The maximum spacing between collars shall be 14 times the projection of the collar above the barrel. Collars shall not be closer than 2 ft to a pipe joint. Collars should be placed sufficiently far apart to allow space for hauling and compacting equipment. Connections between the collars and the barrel shall be watertight.

16.6.12.2.7 Emergency Spillway

The emergency spillway (see Figure 16-14) shall consist of an open channel constructed adjacent to the embankment over undisturbed material (not fill):

Capacity — The emergency spillway shall be designed to carry the peak rate of runoff expected from a 10-yr storm, less any reduction due to the flow through the principal spillway.

Design Elevations — The design high water through the emergency spillway shall be at least 1 ft below the top of the embankment. The crest of the emergency spillway channel shall be at least 1 ft above the crest of the principal spillway.

Location — The channel shall be located to avoid sharp turns or bends. The channel shall return the flow of water to a defined channel downstream from the embankment.

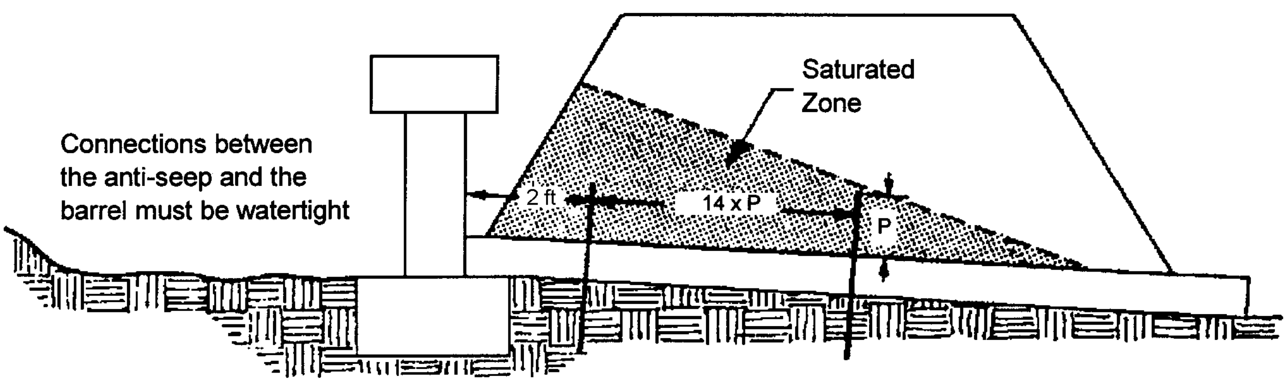


FIGURE 16-13 — Anti-Seep Collars

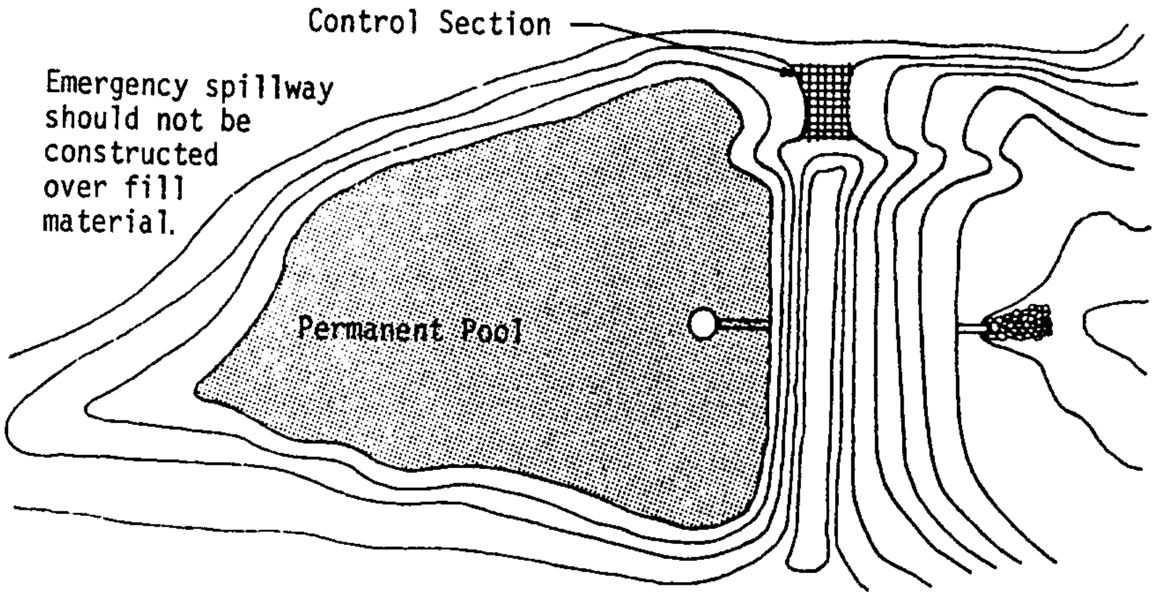


FIGURE 16-14 — Emergency Spillway

Maximum Velocities — The maximum allowable velocity in the emergency spillway channel will depend upon the type of lining used. See the Channels Chapter for allowable velocities.

Cleanout — Sediment shall be removed from the basin where the capacity is reduced to 64 m^3 per hectare of drainage area.

16.6.12.3 Construction Guidelines

16.6.12.3.1 Site Preparation

Areas under the embankment and any structural works shall be cleared, grubbed and stripped of topsoil to remove trees, vegetation, roots or other objectionable material. To facilitate cleanout and restoration, the pool area (measured at the top of the principal spillway) will be cleared of all brush and trees.

16.6.12.3.2 Cutoff Trench

When a cutoff trench is specified, it shall be excavated along the centerline of the dam. The minimum depth shall be 2 ft. The cutoff trench shall extend up both abutments to the riser crest elevation. The minimum bottom width shall be 4 ft but wide enough to permit operation of compaction equipment. The side slopes shall be no steeper than 1V:1H.

Compaction requirements shall be the same as those for the roadway embankment. The trench shall be drained during the backfilling/compacting operations.

16.6.12.3.3 Principal Spillway

The riser of the principal spillway shall be securely attached to the barrel by a watertight connection. The barrel and riser shall be placed on a firm, compacted soil foundation. The base of the riser shall be firmly anchored according to design criteria to prevent its floating. Pervious materials (e.g., sand, gravel, crushed stone) shall not be used as backfill around the barrel or anti-seep collars. Fill material shall be placed around the pipe in 4-in layers and compacted by hand at least to the same density as the embankment. A minimum of 2 ft of fill shall be hand compacted over the barrel before crossing it with construction equipment.

16.6.12.3.4 Emergency Spillway

Design elevations, widths, entrance and exit channel slopes are critical to the successful operation of the spillway and should be adhered to closely during construction.

16.6.12.3.5 Embankment

The fill material shall be taken from approved borrow areas. It shall be clean mineral soil and free of roots, woody vegetation, oversized stones, rocks or other objectionable material. Areas on which fill is to be placed shall be scarified prior to the placement of fill. Fill material will be placed in 6-in to 8-in continuous layers over the entire length of the fill. Compaction shall be obtained by routing the hauling equipment over the fill so that the entire surface of the fill is traversed by at least one wheel or tread track of the equipment or by using a compactor.

16.6.12.3.6 Vegetative Stabilization

The embankment and emergency spillway of the sediment basin shall be stabilized with temporary vegetation within 15 d of completion of the basin.

16.6.12.3.7 Erosion and Sediment Control

The construction of the sediment basin shall be performed such that it does not result in any undue sediment problems downstream.

16.6.12.3.8 Safety

All State and local requirements shall be met concerning fencing and signs warning the public of the hazards of soft sediment and flood-waters.

Note: For a detailed discussion of design procedures and specifications for temporary sediment basins, see Reference (4), Appendix 1.26A.

16.7 EROSION SEDIMENT CONTROL PLAN

16.7.1 Control Plan

Simply stated, an erosion and sediment control plan is a document that describes the potential for erosion and sedimentation problems on a construction project and explains and illustrates the measures that are to be taken to control those problems. The plan has a storm water pollution prevention plan cover sheet known as a narrative and an illustrative portion known as a map or site plan. This plan, including standards and specifications, should be a part of the contract documents.

16.7.2 Plan Development Procedures

The length and complexity of the plan should be commensurate with the size of the project, the severity of site conditions and the potential for off-site damage. A narrative may be necessary for complex projects.

Step 1 Data Collection And Preliminary Analysis

The highway construction plans can serve as the base map for the erosion control plan. If available, a soils map should be obtained from the local office of NRCS. The designer responsible for the plan should inspect the site to verify natural drainage patterns, drainage areas, general soil characteristics and off-site factors.

The base data should reflect such characteristics as:

- land slopes;
- natural drainage patterns;
- unstable stream reaches and flood marks;
- watershed areas;
- existing vegetation (noting special vegetative associations);
- critical areas (e.g., steep slopes, eroding areas, rock outcroppings, seepage zones);
- unique or noteworthy landscape values to protect;
- adjacent land uses, especially areas sensitive to sedimentation or flooding; and
- critical or highly erodible soils that should be left undisturbed.

In the analysis of these data, identify:

- buffer zones;
- areas of steep, natural and man-made slopes;
- stream crossing areas;
- access routes for construction and maintenance of sedimentation control devices;
- borrow and waste disposal areas;
- the most practical sites for control practices; and
- potential for sediment pollution of adjacent water courses and properties.

When all data are considered together, a picture of the site potentials and limitations should begin to emerge. The designer should be able to determine those areas that have potentially critical erosion hazards.

Step 2 Plan For Erosion And Sediment Control

The following general procedure is recommended for erosion and sediment control planning:

A. Determine limits of clearing and grading. Decide exactly which areas must be disturbed to accommodate the proposed construction. Pay special attention to critical areas that must be disturbed.
B. Divide the site into drainage areas. Determine how runoff will travel over the site. Consider how erosion and sedimentation can be controlled in each small drainage area before looking at the entire site. Remember, it is easier to control erosion than to contend with sediment after it has been carried downstream.

C. Select erosion and sediment control practices. Erosion and sediment control practices can be divided into three broad categories — vegetative controls, structural controls and management measures (see below). Management measures are construction management techniques that, if properly utilized, can minimize the need for physical controls and possibly reduce costs.

Vegetative Controls

Remember that the first line of defense is to prevent erosion. This is accomplished by protecting the soil surface from raindrop impact and overland flow of runoff. The best way to protect the soil surface is to preserve the existing ground cover. Where land disturbance is necessary, temporary seeding or mulching can be used on areas that will be exposed for long periods of time.

Erosion and sediment control plans shall contain provisions for permanent stabilization of disturbed areas. Selection of permanent vegetation should include the following considerations:

- establishment requirements,
- adaptability to site conditions, and
- aesthetics and maintenance requirements.

Structural Controls

Structural practices are generally more costly, require greater maintenance and are less efficient than vegetative controls. However, they are usually necessary because not all disturbed areas can be protected with vegetation. They are often used as a second or third line of defense to capture sediment before it leaves the site.

It is very important that structural practices be selected, designed and constructed according to UDOT's standards and specifications. Improper use or inadequate installation can create problems that are greater than the structure was designed to solve.

Structural controls also include the permanent drainage facilities. These should be constructed as early as possible.

Management Measures

Good construction management is as important as physical practices for erosion and sediment control, and there is generally little or no cost involved. Following are some management considerations that can be employed:

- Sequence construction so that no area remains exposed for unnecessarily long periods of time.
- On large projects, stage the construction if possible so that one area can be stabilized before another is disturbed.
- Develop and carry out a regular maintenance schedule for erosion and sediment control practices.
- Make sure that all workers understand the major provisions of the erosion and sediment control plan.
- Responsibility for implementing the erosion and sediment control plan should be designated to the Environmental Control Supervisor.

Step 3 Prepare The Plan

The final Step consists of consolidating the pertinent information and developing it into a specific erosion and sediment control plan for the project. The Storm Water Pollution Prevention Plan consists of cover sheet, plans, standard drawings and specification.

16.8 REFERENCES

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